The Institute of Physics

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The Bulletin is published by The Institute of Physics for circulation to its members.

Notices to Members

Annual Dinner

The President wishes to remind members of all grades that he specially desires that they and their ladies will support him at the Institute's first Annual Dinner on Wednesday, March 26, at the Savoy Hotel, London. Members' guests will be particularly welcome. Details with application forms were circulated with the January *Bulletin* and further copies will be sent on request. The closing date for applications is February 28.

Physical Society Exhibition

The Physical Society's 42nd annual exhibition of instruments and apparatus will be held in the Halls of the Royal Horticultural Society, Westminster, London, S.W.1, from March 24-27 (inclusive).

Members of the Institute who are not members of The Physical Society may obtain tickets for the exhibition, available for any one day, on application to the Institute.

Payment of Annual Fees

Members are reminded that annual fees became due on January 1. Members requiring duplicate copies of the reminder published in the January *Bulletin* may obtain them from the Secretary.

Non-Destructive Testing Group — Summer Conference

The Non-Destructive Testing Group is planning its Summer Conference as a joint meeting with the Société Française de Métallurgie in Paris from June 16 to June 20, 1958. Non-members of the Group may obtain details from the Group Honorary Secretary.

The Institute's Membership

THE rate of growth of membership is some indication of the Institute's health and of the extent to which the work that it endeavours to do secures the support of practising physicists. The two diagrams show the very satisfactory rate at which membership of the various grades has increased : Fig. 1 gives curves of total membership (including Students and Subscribers) and of the total of the three grades (Fellow, Associate and Graduate) for which acceptable academic qualifications in physics are demanded. Separate curves for these three grades are given in Fig. 2.

Over the years the requirements for corporate membership (Fellowship and Associateship) have been progressively stiffened, especially those relating to the length and quality of professional experience. The standards of professional training and competence now implied must be among the highest asked for by professional bodies.

Table I analyses the occupations of Fellows, Associates and Graduates elected in 1956 and 1957.

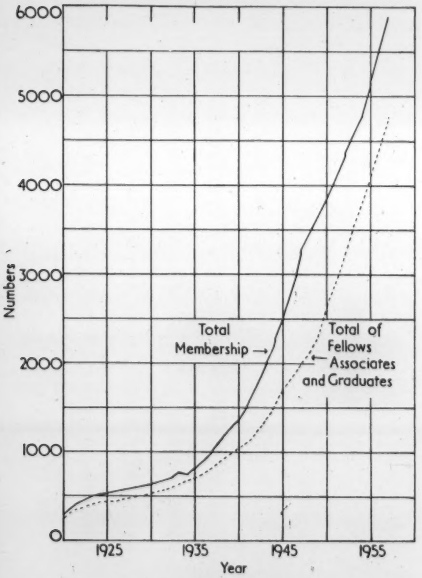

Fig. 1. *Total membership and total of grades requiring acceptable academic qualifications*

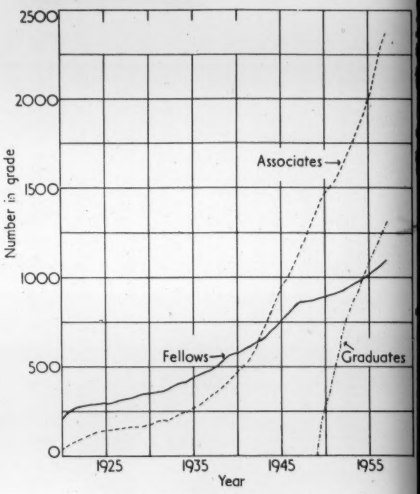

Fig. 2. *Numbers of Fellows, Associates and Graduates*

TABLE I. *Elections to Fellowship, Associateship and Graduateship*

	Fellows 1956	1957	*Associates* 1956	1957	*Graduates* 1956	1957	*Total* 1956	1957
Industry - - -	18	10	117	87	101	101	236	198
Government Service	4	14	33	23	11	17	48	52
Universities :								
Staff - - - -	9	17	33	18	2	5	44	40
Research Students etc. - - - -	–	–	4	4	61	59	65	63
Public authorities (mainly Atomic Energy Authority)	1	2	15	17	14	24	30	43
Technical Colleges -	4	5	20	32	10	5	34	42
Schools - - - -	–	–	18	12	8	13	26	25
Research Assns. -	4	2	7	9	5	1	16	12
Hospitals - - -	4	1	6	5	2	1	12	7
Others - - - -	2	2	15	5	15	4	32	11
Totals - - -	46	53	268	212	229	230	543	493
New admissions (i.e. not transfers) included in the totals	8	15	155	122	167	159	330	296
Allowing for transfers from the Student grade and for losses due to death or resignation : Net Increase in graduate members - -							338	310
For comparison : Net increase in 1937 - - -								68
Net increase in 1947 - - -								112

Vol. 9, February, 1958

Physics and Aesthetics *

By F. I. G. RAWLINS, M.Sc., F.S.A., F.R.S.E., F.Inst.P.

(*Scientific Adviser, The National Gallery, London, and Technical Director of The Central Council for the Care of Churches*)

THE theme which I have the pleasure of submitting to you is one to which a certain amount of unconscious, or perhaps subconscious, attention is being paid in various parts of the world, and by a variety of people. And further, there is manifestly some degree of divine discontent with things as they are, relating to the very basis upon which much of present-day physics rests as an accomplishment of trained minds in this mid-twentieth century. Thus, I believe, it will not be inappropriate to "think aloud"—so to speak—before the Institute's Education Group on the deep questions involved in the relations between *scientia* (as knowledge) and the Beautiful or, more briefly and narrowly, "Physics and Aesthetics."

On the surface, many facets of this particular crystal will come up for consideration, not least the place of the historical method in our whole concept of natural philosophy (as I like to think of physics as she is apprehended north of the Border). Again, and this Body scarcely needs a reminder, physics is a fundamental discipline (only once removed from mathematics and logistics), but this is no reason why a grounding in such a science should necessarily mean a life devoted to measurement and direct observation. Classical scholars and historians take up all sorts of vocations, only indirectly concerned with the dead languages and the passage of time in its effects upon mankind.

So physicists should sometimes, I suggest, become philosophers, and maybe students of aesthetics. That it is difficult for them to do this, I cannot deny : it has recently been stressed that such lack of fundamental thought as exists is the price we have to pay for specialization and the mastery which it brings. Probably this is not far from the truth, and a grave issue for a (largely) industrialized society. But then it is never easy to set out across country, travelling light with not-too-clear a tryst in view. We are all children of our generation, more or less, and speaking for myself as a graduate of 1926, I would say that for, roughly, the last quarter of a century, physics has been living over-much on her capital (how true this was of the war years especially), with the result that it is becoming ever harder and harder to raise new money for investment. This metaphor is not too far-fetched. Last year, I interviewed a number of young graduates from the two ancient universities for a particular scholarship. Only one—not from my own *Alma Mater*—showed any awareness that natural science could have any direct bearing upon the arts, or they upon it. (Incidentally, this candidate was an accomplished musician.) The rest would never be philosophers of the type I have in mind, because they could not see that the co-existence of accurate knowledge and aesthetic sense constitutes a profound problem. And, of course, philosophy recognizes problems as problems, even if for centuries no solutions to them are found. A topical example is Fernat's last theorem, enunciated in 1637—asserting the impossibility of factorizing into integers the equation $x^n+y^n=z^n$ if n is greater than 2. A proof was reported from Pakistan on November 9 last. If valid, it will be an aesthetic triumph. All this is not, naturally, to decry physics—far from it—but it is to examine very closely where we are going, if young manhood and womanhood are to be saved from frustrations and disappointments of a very distressing kind. It may well be that in applied physics—as perhaps in engineering—certain natures will find due satisfaction, not only from day-to-day, but with the finished product in which they have so great a share. But sooner or later, and willy-nilly, will come the criterion, first posited in its present guise by that great philosopher of Manchester, Samuel Alexander (1859-1938), who remarked that, when we have made something, the discriminant as to whether or not it is an aesthetic object is our capacity to sit down quietly and contemplate it. And this, not in the least bothering whether it is useful or not, but whether, then and there we derive satisfaction from it for what it is. For example, many of the actions and reactions of classical physics are presented by the act of throwing a vessel upon the potter's wheel. The upshot may be something worth contemplating ; it may even be beautiful. There is an element of teleology here, to which a

*A lecture given to the Education Group of the Institute on December 4, 1957

passing reference will be made later : in brief, the potter knows in his own mind what " end " he desires to attain, and if he cannot do so by one " path " he will try another, in much the same way that " directiveness " works in biology.

It is this element of contemplation which is vital. How otherwise, for example, could Sir Henry Pollock, himself a senior Wrangler, write to De Morgan in 1869 saying that Samuel Vince (Plumian Professor of Astronomy and Experimental Philosophy at Cambridge from 1796-1822) " was a bungler, and I think utterly insensible of mathematical beauty." Once more, in our own day, we find Dirac preferring methods involving the use of the complex variable to that of the matrix calculus because the former was the more beautiful. But perhaps above all, there is the deliberate act of Leonardo da Vinci in laying aside for a while his pencil and brush to study the works of Archimedes. What effect this had upon the great artist may be seen in the attention he gave to the design of machines of various and strange types, and in his veneration for natural law. Actually, he obtained a copy of the works from the Bishop of Padua (I have never been able to make sure whether he returned it), and immersed himself in it. As is common knowledge, the process was not wholly successful, since Leonardo was incapable of generalization and of this kind of abstraction. But the point is that of discipline. " Having not the mathematics," as we might say, he yet acknowledged their power, and was of great enough mental stature to perceive (and even to rejoice in) the inherent beauty of Greek statics. It was contemplation incarnate.

Another aspect of this same property comes from the works of John Ruskin. As you may recollect, all through that vast bulk of *Modern Painters* (five volumes of detailed analysis), he never tired of stressing the majesty of nature, not quite like Goethe, with his extreme subjectivism, but rather more as a descriptive geologist might have done. But on one occasion, Ruskin opined that if he were offered the choice of a view of a certain landscape, and a painting of that same landscape by Turner, he would immediately prefer the former. Now, having regard for the veneration with which Ruskin regarded Turner, and all his works, this is a somewhat remarkable confession, and illustrates, from a particular angle, this element of contemplation. We may safely make the rather trivial assumption, I think, that Ruskin could have permanent access to his beloved natural landscape whenever he wished, as well as permanent possession of Turner's rendering of it. Purely physically, scanning the real landscape for detail might involve an angle of say 45° for the eye to cover, whereas for the picture, supposing a normal-sized canvas, something like 10° would suffice, a substantially smaller output of visual energy. So, contemplation in our sense is not just " mooning," it is the employment of a high level of mental tension interested in " squeezing the lemon dry "—as a scientist does—of all relevant perception, in an effort to absorb the full content of the beautiful, as meaningful and purposive. I have dwelt at the outset with this habit, if so it may be called, of contemplation because it seems to be quite fundamental in the whole sphere of ratiocination, both scientific and philosophical. Moreover, as might be expected, it is very hard work indeed, harder than much observational physics, and attaining near-identity with the cerebral flux which immediately precedes great discovery. Knowledge advances, as the late Lord Rutherford used to insist, by the development of technique. He was thinking primarily of laboratory processes, but the dictum is none the less true of mathematical prowess as when, for example, George Boole (in effect the founder of modern symbolic logic) laid the basis for his great book *The Laws of Thought* sitting under a bush in the flat country bordering the river Trent, or when Sir William Hamilton finally brought the first quaternion into being, and ran up to a tree in Dublin to scratch the classic formula upon its bark. And mankind has done much the same in vicarious regard for departed genius, as witness " 2 : 3 " upon the grave of Archimedes or the " $S = k \log W$ " upon that of Ludwig Boltzmann. These two examples are interesting sidelights upon the value we place upon mathematical aesthetics (for both theorems are beautiful), but the searching question is, should they be thus perpetuated ? In so far as they are master-achievements, perhaps " Yes," but in so far as they are but human concepts, born of time, perhaps " No." But one thing is certain—they escape the Greek veto upon all permanent memorials of conquest. Any such, in the great days of the City State were to be of wood so that they might perish, leaving no overt sign of bitterness to endure. So much for contemplation in its historical and social setting. It has taken pride of place to some extent, because I was anxious that aesthetics—a term introduced by Baumgarten about 200 years ago—should not be regarded as a typical dilletante attitude, to be grown out of as soon as maybe. For contemplation means strife, for the beautiful is capricious. In the hope that I shall survive this talk without introducing definitions, it is now desirable to add a correlate to beauty, and that is symmetry. At

this stage, the scientist will recognize something that crops up time and time again in the course of his normal activities—in geometry, in the theory of algebraic forms, in skew-symmetric equations, in all branches of topology and crystallography, not to mention wide domains of chemistry and biophysics. But this implied coupling of beauty and symmetry in a species of homopolar bond would not have pleased the philosopher Plotinus at all, who regarded the beautiful as " single " and therefore devoid of all possibility of symmetry as we understand it. For him, art could supply something that nature lacked, a view - point opposed in the main to the orthodox Aristotelianism of his time. Yet there is no real clash here : the Stagirite was initially a master of taxonomy, and his criteria synthetic rather than analytic so far as " system " was concerned. We shall touch later upon his particular concept of cause, of great importance to both scientist and philosopher. Meanwhile, Aristotle has probably contributed more to our subject than Plato and his abstractions.

Plato considered ideas as pure forms, and the sum of such forms as they became real (realized) constituted the world. As his philosophy developed, it seems likely that his concepts became more numerical ; it may be that this was a throwback to the school of Pythagoras some two centuries earlier, and to whom the five regular polyhedra were probably known. The half-century (roughly) between Plato and Aristotle shifts the balance significantly in that the latter distinguishes form from matter and postulates a striving (of universal character) towards form. It is this form which possesses qualitative essence, though related to quantity. In brief, we find the thirteenth century philosophers at Oxford building upon this foundation, with Albertus Magnus across the water establishing something like a hierarchy of organic forms, thus paving the way for the kind of speculation which has produced the most creative biophysics to-day. St. Thomas Aguinas following Aristotle raises the scholastic doctrine of form to its highest level in " equating" it to the basic principle of activity. It is true that many of these processes involve an element of teleology, which was repulsive to the minds of Victorian scientists, but by no means so readily rejected by the most recent tenets of the quantum theory as seen by e.g. de Broglie and Bohm.

It will not have passed without notice that " form " has been introduced as a concept which has been slowly germinating in men's minds in so subtle and pervasive a way as to have come to stay without being invited. The fact is that we all know in ourselves what " form " is, e.g. the form of a crystal, a drop, a soap-bubble, a chain hanging between two posts as the locus of a catenary, and so on. Yet physics cannot exactly explain form, starting from *a priori* reasoning, if by that is meant " true no matter what." But it is not my function to defend form, or any of its correlates. That has been done with distinction in that collection of essays (with Mr. L. L. Whyte as Editor) under the title *Aspects of Form*. What is our concern just now is how (if at all) we can recognize certain forms or combinations of forms as beautiful, and if so whether there are any mathematico-physical laws which, however indirectly, may help us to do so, and thus to bring about some degree of concord, however tentative, in the domain of aesthetic judgement. (That heavily overworked word " crisis " philologically means " judgement " and those who talk of crises in the arts and sciences are in duty bound to seek a judgement of some kind in these matters ; in that they speak more truly than they sometimes intend). The complexity here is that by common consent, there are two regions of aesthetic measure, the formal and the connotative, and that the first is much less intractable than the second. Formal aesthetic features are factors like proportion and tangency relations in vases, rhythm in poetry and music, pattern in decoration and so on. Connotative questions concern human reactions and impulses. Birkhoff in his book *Aesthetic Measure* has made a very substantial contribution to our knowledge of formal aesthetics by his system of geometric elements and his " figure of merit " (as it may be called) $M = O/C$. This seemingly simple expression can become quite involved, due to the elaborate factors inherent in the " order " O, and the " complexity " C. The method may perhaps best be illustrated by reference to vase forms, wherein it is necessary to draw an outline or contour of the vessel, and so distinguish certain singular points upon the periphery and to note the ratios existing between their horizontal and vertical " joins " ; coupled with certain tangency relations. The resulting set of values for M does—odd as it may appear—stand in a satisfactory way to the order of aesthetic merit in which reasonably competent judges would arrange the vases. If it be objected that the singular points and the tangency relations associated with them are too arbitrary, Birkhoff would probably reply that these parameters are just those which any thoughtful person would in fact select to "describe" the object. Naturally, all this has nothing whatever to do with colour (local or general) or with pattern : the parameters are purely geometrical constructs dependent upon two-dimensional forms.

Very likely, the plan suffers from over-simplification but, as far as I know, it is the best attempt yet made to evolve some kind of scale of aesthetic values. Birkhoff's equation gives quantitative expression to the age-long recognition that unity-in-variety is an essential element in our demands upon what may be accepted as beautiful.

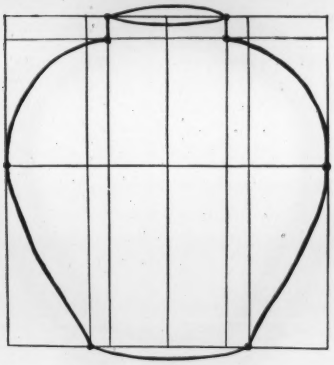

Figure 1. PROFILE OF VASE

As an example consider the vase-profile illustrated. The eight points marked are those upon which the eye would naturally fasten in looking at the figure. These points are, those at the top and neck, those at the " equator " and those at the base, eight in all. So the complexity is $C = 8$. In addition, we have the following geometrical relations.

(i) The diameter at the foot is half the " equator."

(ii) The lip and neck are cylindrical. Therefore there are two horizontal parameters.

(iii) Also, the height equals the equatorial width. Therefore the total for $O = 3$ and the aesthetic measure $M = O/C = 3/8 = 0.37$.

In fact this is a T'ang vase of comparatively low " merit " (M can exceed unity in rare cases) but it has been chosen to exhibit the principles of Birkhoff's work with the minimum of arithmetical boredom.

As already indicated, this formal system provides something like a numerical guide to the classification of aesthetic objects, but as will readily be appreciated, it cannot be used to compare the relative merits of—say—a piece of architectural decoration with a phrase of a symphony. It only applies to " like with like." (Otherwise, it might have solved that distressing problem which confronts university and college examiners from time to time when a limited number of prize fellowships in any academic subject has to be awarded, the candidates having submitted meritorious theses on perhaps Confucianism, the propositional calculus, and genetics. Who is to assess their relative intellectual worth in common terms ?)

But there exists nevertheless a great profusion of artistic treasure based upon quasi-mathematical principles, e.g. mosaics designed in obediance to the theorem of Pythagoras, the imperfections being made good with small areas of putty in much the same way that the modern crystallographer introduces " lockerstellen " to allow of " real crystals." The patterns on ancient shields, the decorative treatment of Greek pottery (apart altogether from shape as such) and more recently, the near-identity between mathematical models and abstract art, all show a tendency not only to use algebraic and geometric forms, but openly to acknowledge their necessity. I have little experience in teaching myself, except during a brief period at Cambridge for the Natural Sciences Tripos, but I should not be surprised if " curve-tracing " as a fairly elementary exercise, brought out students' abilities, not only as mere problem solvers, but as possessors of imagination. The " forms " in question, e.g. the cardioid, the cissoid, the tractrix, the spirals and the witch of Agnesi are individually lovely.

We are now at the frontier between the formal and connotative regions of aesthetics, and before crossing the border I would like to draw your attention to what I believe to be a fallacy and to invoke some historical evidence in support of this view. The attitude to which I refer is that which asserts that the enjoyment of a work of art is diminished in some way by the analysis of its structure and constitution. After some twenty-odd years at the National Gallery, I have never come across a serious student or scholar who did not welcome every new type of knowledge, philosophical or technical, which could be brought to bear upon the visual image or upon its message in respect of any great picture in the national collection. And not a few upholders of this liberal doctrine are, or were, leading names in the world of science. A perfect exponent would be the late Professor D'Arcy Thompson, the author of *Growth and Form*, who saw in all cases of morphogenesis the manifestation of mathematical and biophysical beauty. But historically, great

artists like the founders of perspective, Piero della Francesca, Leonardo da Vinci, Brunelleschi, Michelangelo and others, actually constructed some of their pictures and decorations for the sheer joy of demonstrating their discovery and the mastery they had obtained in applying it. Andrea Pozzo—who was born in the same year as Newton—may not have been a supreme artist, but his skill in portraying concave and convex surfaces was remarkable. The beholder of to-day misses a great deal if he fails to read all the reason he can into a great artist's work. One suspects that an unwillingness to do this results from too strong a regard for subjective factors, though as elsewhere, faith may take over when reason is exhausted.

With some trepidation, born of several years of thought on the subject, I now approach the difficult connotative region of aesthetics, i.e.—as we have seen already—that part of the subject especially concerned with our own reactions and evaluation of artistic objects. It is still the intention to retain a strictly scientific attitude, though it will be conditioned by some infiltration of psychology. The basic need here is for a clarification of our ideas of form, and for this purpose the *Gestalt* theory (initiated about the year 1912) stands ready to hand, for what use we may be able to make of it. The German word defies exact translation ; it means all at once, shape, configuration, form, with particular stress upon its integrative quality, and I propose to use it accordingly, but it is this integrative sense that matters—the whole is more than the sum of its parts. A *Gestalt* is not a mere " and – summation," as the Germans put it, like (a and b and c and d) but something other and distinctive, in which a, b, c, d, have lost their individual identity in the mental fusion of the whole. Associated with the *Gestalt* concept is the so-called law of *prägnanz* according to which any system tends to the "best" possible state open to it, where " best " means " ordered," " balanced," " symmetrical," etc., or perhaps, if not too picturesquely, a state of repose. So here we meet again in a slightly different dress, our previous concept of " organization " as essential to every kind of aesthetic satisfaction. Recollecting what has already been said on the historical development of aesthetics, this is in the nature of a throw-back to Aristotelian principles, rather than to Platonic.

Now, as an intellectual adventure, I am going to suggest that a great work of art, in particular a picture, is a *Gestalt*. (The theorists would make me qualify it as a " weak " *Gestalt*, for sundry reasons connected with the mental process, but that does not affect the main theme). Assuredly, such a composition possesses balance, organization, wholeness, a purposeful pattern, and is very much more than the sum of its parts. It embraces harmony and—almost by definition—satisfaction and repose. At least it illustrates as a visual object, the law of *prägnanz* in practice. The next proposition is that it is possible, in principle, to follow the various stages in the building up of this picture, and thus to recognize an " extremum " as a position of minimal energy when equilibrium will have been reached. So that in the usual functional form $y = f(x)$, free-energy is a function of the organization (in the *Gestalt* sense) and that a minimal value will occur somewhere. It will be observed in passing that our expression is dimensionally of the nature of a potential, for the area under the curve is energy × a geometrical factor. Thus, as the work progresses, we can imagine a curve E, each stroke of the brush either lowering, or perhaps raising, the energy as the organization develops. The crucial point is E_{min} at a certain O value. If the artist overshoots this critical value of O, E rises and the result is not the " best " in the *prägnanz* sense. But it is interesting to note that E_{min} is often approached (from the left) very gradually, but E increases rapidly after E_{min} has been passed. Organization has then been overdone and has become a defect. The experimental evidence for all this is briefly as follows. In certain instances, X-radiographs and infra-red photographs reveal progressive changes in the position of a limb, e.g. a hand as the artist has changed his mind perhaps several times as regards posture or stance. This process is roughly akin to the mathematician's iteration, or successive approximation in that each modification comes slightly nearer to the artist's concept of satisfaction. It is in fact the law of *prägnanz* in action. But the intriguing thing is that one gets a deeper and deeper sense of repose or equilibrium with each successive alteration as we go along—so to speak—the O axis of our graph. Meanwhile, the E values may be thought of as decreasing to the value E_{min} when luckily the artist stops at what he takes to be the " best " effect. I am not putting this forward as a proof of anything—that would be to go much further than our experience warrants. But the effect is found rather too often to be mere chance. From this one might conjecture that, rightly or wrongly, creative artists do function in this " potential " fashion, and that modern physical methods have enabled us to follow them (in favourable cases) many centuries after the event. These phenomena are commonly called *pentimenti* by art-historians. Due to the rise of

Figure 2. JAN VAN EYCK
The Marriage of Giovanni Arnolfini (?) and Giovanni Cenami (?)
Infra-red detail (×2) of clasped hands, showing changed position of thumb
(*By courtesy of the Trustees of the National Gallery*)

refractive index of the paint-medium with age, they sometimes become visible to the naked eye, needing no special photography at all.

Somewhat analagous considerations can be applied to what may be termed the environmental character of art, which is part of art history in much the same way that social and other human factors are embedded in the history of science itself. Thus, the laws of Le Chatelier and of Mass-Action in physical chemistry are both examples of the realization that at once something happens, and would of itself go forward, opposing forces come into action tending at the least to inhibit and possibly even to reverse whatever it is that is taking place. In the initial stages, a catalyst may be needed before anything occurs at all. Schools of painting have been started by some national or local upthrust and have gone ahead merrily enough until saturation is reached. And by this I mean saturation of intention or content, as the case may be, and not of course mere stagnation in demand. Wrapped up with this has sometimes been the need for an interpreter. Ruskin performed this role for many a year on behalf of the English Pre-Raphaelites, and Thoré is known to have done much the same for the Barbizon school in France. The intervention of these missionaries is like renewing the active substances in a continuous industrial works process so that the sequence of events does not end in a premature stop. Much mediaeval art encountered formidable opposition when, as sometimes happened, it was not sponsored by patrons of appropriate influence.

Before finally leaving the *Gestalt* concept, it should of course be abundantly clear that broadly similar considerations of minimal energy, the satisfaction of the law of *prägnanz*, and of the integrative principle apply in greater or less degree to all works of art, including architecture as a special case. Whether we are interested in—say—the "Central Church" of the humanists of sixteenth-century Italy, the Baroque (or Rococo) which followed, or our own typical and devotional English Gothic, the fact remains that one cannot subtract any part of these great buildings without doing violence to the whole. This is not because they necessarily all exhibit a strict unity of design

(Salisbury Cathedral does, whereas Ely is a wonderful mixture) but because they are never mere " and-summations." The whole is always very much more than the sum of its parts. A very early illustration of the nature of a *Gestalt* was given by Wertheimer ; a company of musicians playing odd notes at random make nothing but noise and confusion, whereas when acting according to an overall plan in sequence, order and rhythm, they produce a melody. Again, the whole is immensely greater than the sum of its parts. Physically, the laws of fugue, point and counterpoint are all concerned with the components of organization of the composition, obeying in qualitative fashion the law of *prägnanz*.

At this point, to round off the discussion of a work of art as a formative event, it may be convenient to recollect Aristotle's conception of cause, which was in some ways much wider than ours. Thus, he thought of (*a*) the *material* cause, (*b*) the *formal* cause, (*c*) the *efficient* cause, (*b*) the *final* cause, In our present plane of discourse, these would be (*a*) the wood, stone, paint or whatever the substance involved might be, (*b*) the finished picture, vase, or building, (*c*) the artist, potter or architect, and (*d*) his message or intention. Looking at our problem in this decidedly classical light is interesting, because it helps to bring the agent and the object he makes into a closer relationship than perhaps in any other epistemological system. When one bears in mind the modern view that Aristotelian logic contributes but a trifle to the whole discipline commonly so called, it is tempting to speculate upon how rich a field might be thrown open by the use of twentieth century three-valued logistics in the domain of aesthetics. It has already been pointed out by the late Sir Edmund Whittaker that metaphysics may well return to an honoured place within the sciences if it will but be critical towards itself and its own basic pre-suppositions. And much the same applies to aesthetics, whose followers must needs tread the way of sorrows if they are to achieve scientific recognition.

Having sketched the features, attenuated as they may be, of the connotative region of aesthetics (in so far as it is feasible to deal with them by any approach to scientific principle), it may now be desirable in conclusion to make one more attempt to examine the " potential " of beauty rather more deeply. Here we are in possession of a doctrine due to Stace (1929) which takes some account of human cognition. Stace defines beauty (B) as " the fusion of an intellectual content (I.C.), consisting of empirical non-perceptual concepts with a preceptual field (P.F.) in such manner that the intellectual content and the perceptual field are indistinguishable from one another, and in such manner as to constitute the revelation of an aspect of reality." Stace asserts that the fusion must be as complete as that which results from true chemical combination (a decided hark-back to the *Gestalt* imagery), and productive of something essentially new. Thus, a quasi-equation would be

(I.C.) + (P.F.) work of artist (B) + Aesthetic pleasure.

Supposedly the action is strongly endothermic, since much labour is obviously needed to bring (B) to fruition. That (B) and aesthetic pleasure must reach some sort of balance is clear, otherwise our satisfaction would be evanescent. The inference, perhaps, is that the resulting organization must correspond in some way to a position of minimal energy, a state of affairs we have met already.

When a subject is in an early stage of development one must needs be content perhaps with trifling progress and shaky steps. This is the most which I can claim for my theme this evening. It has no sort of finish, except the attempt to present it in not too ungainly a form. The biologists would probably, if they exercised sufficient charity, see in it an example of morphoplasticity, the emergence of something as the result of a fair amount of pounding.

But little save experience counts in the end, and this has never been expressed more nobly than by Alfred North Whithead in his *Adventures of Ideas* (pp. 290–1, 1943)—" Experience drunk and experience sober, experience sleeping and experience waking, experience drowsy and experience wide-awake, experience self-conscious and experience self-forgetful, experience intellectual and experience physical, experience religious and experience sceptical, experience anxious and experience care-free, experience anticipating and experience retrospective, experience happy and experience grieving, experience dominated by emotion and experience under self-restraint, experience in the light and experience in the dark, experience normal and experience abnormal."

REFERENCES

Birkhoff. *Aesthetic Measure.* Havard University Press (1933).

Rawlins. *Aesthetics and the Gestalt.* Nelson (1953).

Spenser. *Die Mathematische Denkweise.* Birkhauser (1948).

Stace. *The Meaning of Beauty.* Cayne Press (1929).

Whyte (edited by). *Aspects of Form.* Lund Humphries (1951).

Whittkower. *Architectural Principles in the Age of Humanism,* Warburg Institute (1949).

M.K.S. Units in Physics Teaching

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(In his reply to the articles by Mr. Noakes and Dr. Chalmers in the *Bulletin* for June, 1957, Prof. Lipson referred to an article on this topic which had appeared in the *School Science Review*[1]. The writer of that article has contributed the following version of it with modifications necessitated by the appearance of the book *The Teaching of Electricity*[3] and other publications since the original article was printed).

INTRODUCTION

The practical convenience of the m.k.s. system for certain types of advanced and technical work has led to a strong campaign for introducing the system into elementary physics teaching. It might be thought that the mere introduction of a convenient set of units was a relatively trivial matter which would not affect the method and sequence of teaching a subject. Nevertheless, in this case there are features of the system which are difficult if not impossible to reconcile with the traditional approach. In one of the most striking and competent textbooks on electricity appearing in recent years[2] a serious and thorough-going attempt is made to incorporate m.k.s. units into the traditional logical presentation of the subject. A close study of this book will show that, whatever advantages may be gained in the *application* of the results, the development of the subject itself is rendered appreciably more difficult and, in places, less satisfying by the use of the m.k.s. system. This dilemma is as old as the system itself and has led advocates of m.k.s. units to introduce a radically new approach to the whole subject, involving a more or less complete break-away from the historical order of development and, in particular, an abandonment of the concept of the magnetic pole. We shall see later that the artificial distinction between field strength and flux density in free space, which is the basis of the m.k.s. system, contributes more than any other feature to the necessity for the new approach. As we review the novel features of the new method we shall see that they all tend to handicap a student proceeding to the higher branches of the subject or desirous of something more than a rule-of-thumb attitude towards it. It is important to notice that nothing is being said against the m.k.s. system itself; the objections are levelled against the teaching methods it brings with it.

THE FICTIONAL FEATURE OF THE M.K.S. SYSTEM

Many scientific procedures require the use of "convenient fictions" which are generally harmless because everybody concerned understands how and why these concepts are introduced. When, however, the fictional concept is introduced at a particularly critical and (for the student) difficult stage, and when, moreover, the textbooks concerned treat the fiction as solid fact, a great deal of mental confusion is caused. Let us, then, briefly review the main fictional features of the m.k.s. system.

We shall postpone the discussion of rationalization (the insertion of 4π in certain elementary equations in order to eliminate it from others) as this is not an inherent feature of the system although usually linked with it. The central feature of the system is the divorcement of B from H and D from E in free-space fields. The object of this is to enable the coulomb to be used as the unit of charge and the volt as the unit of potential. Thus, to take magnetic units, the use of the ampere and the metre reduces the unit of H to 1/1,000 of its c.g.s. value. B is no longer defined as $H+4\pi\mathcal{J}$ but is defined from flux, φ, the unit of which is fixed by the law of electro-magnetic induction in the form

$$\text{induced e.m.f. in volts} = -\frac{d\varphi}{dt}.$$

The resulting unit of B is of course 10^4 gauss. The ratio B/H for free space (represented by μ_0) is therefore 10^{-7} in the unrationalized system. Similarly in electrostatics E is defined as the number of volts per metre while D is defined in terms of the surface-density ($D=4\pi\sigma$) to which it corresponds. The value of D/E for free space (represented by ε_0) is easily shown to be $1{\cdot}11\times10^{-10}$. Thus both types of field are conventionally endowed with dual properties; each has its flux-density as well as its intensity.

The original and proper function of flux-density is to represent the combined effects of a polarizing field and a polarized medium, as the equations

$$B=H+4\pi\mathcal{J}$$
$$\text{and } D=E+4\pi P$$

indicate. The need for the second field vector arose purely from the existence of magnetically

or electrically polarized media. The notion that field strength and flux density are separate " realities " in free space is thus a fiction which is an integral part of the m.k.s. system. Few writers admit the purely conventional character of this duality but on the contrary try to invest it with an appearance of reality by assigning different dimensions and names to the units of B and H, and by describing the constants μ_0 and ε_0 for free space as the " permeability " and " permittivity," of free space. This nomenclature is suggestive of the attitude of a coalman who buys coal by the ton (weighed on a pair of scales) and retails it by the hundredweight (using a spring weighing machine). Observing that one unit of mass is always connected with 20 of weight he calls this quantity a " universal property of coal."

Much of the discussion of the assumed duality of fields ultimately resolves itself into the question " Do B and H have separate existences in free space ? " Any such concept can be said to " exist " only by virtue of its forming the basis of a hypothesis which explains a great many phenomena. Coulomb's inverse square law and the special theory of relativity are such hypotheses since they are capable of explaining all the phenomena of electrostatics and electro-magnetism without recourse to lines of force, stresses in the æther and similar convenient pictorial models. It is thus a return to the nineteenth century " mechanical æther " to explain these phenomena in terms of the " reality " of a field vector. To go further and argue the separate existence (as " cause " and " effect," for example) of two such vectors is even more out of touch with modern ideas.

We are obliged to accept duality at one or more points in electromagnetism simply because of the fact that relative motion of charges alters their mutual forces. In the traditional approach the duality appears at one point only, namely in the measurement of charge in terms of two absolute units. It is allowable in elementary teaching to regard the static and dynamic behaviour of electricity as two separate properties because it is not practicable to go into the relativistic explanation at this stage. In the m.k.s. system, however, this duality is suppressed (by using the coulomb as the only unit of charge) and caused to reappear at *two* points, namely, in the electrostatic and magnetic field vectors respectively. In these less tangible domains there is unlimited scope for misunderstanding, confusion and fruitless argument.

TEACHING SEQUENCES

The relevance of the foregoing comments to our main theme is seen when we ask the question : " Will the added convenience of abolishing the e.s. and e.m. units in elementary teaching compensate for the necessity of maintaining this artificial view of magnetic and electrostatic fields ? " It is as well to remember that although many pupils will accept the new system without question there will always be some who insist on probing deeper. The physics teacher will either have to maintain the pretence of duality or will be obliged to embark on an explanation which cannot be complete without the consideration of matters far above the elementary level.

There is no denying that young people find electricity and magnetism a good deal more difficult than other branches of physics. It is thus doubly important that we should do nothing to put added difficulties in the early stages of the subject. On the classical system of instruction it is possible to proceed in a series of logical steps, each intellectually satisfying and depending only on what has gone before. The young mind can at any stage rehearse all the steps back to the fundamental principle of the inverse square law : " What is D ? " " D is a vector defined as E times the dielectric constant." " What is the dielectric constant ? " " It is the ratio of potentials (and hence of field strengths) in a condenser with and without the dielectric." "What is field strength?" " It is the force on a unit charge placed at the point in question " and so on. A similar (though not identical) sequence of steps is possible in magnetostatics. When the student comes to deal with more advanced topics in electromagnetism he will find the same sequences of steps, expressed in more general terms, but unaltered in physical meaning.

With the m.k.s. system, however, no such logical sequence is possible, chiefly because of the duality in the field vectors. The elimination of the magnetic pole as an auxiliary concept aggravates matters. These factors lead to the deplorable looseness of the new teaching methods, which we shall illustrate by referring to the Science Masters' Association book *The Teaching of Electricity*[3] to which Prof. Lipson and other writers in the *Bulletin* have alluded.

We find, as we should expect, that magnetostatics and the magnetic pole are cold-shouldered, though the reason given is surprising. It is that " permanent magnetism is still a little-understood anomaly in an otherwise well-documented electromagnetic world." The ampere is therefore defined in terms of the mutual forces between parallel currents. The volt is next defined as that p.d. which involves the expenditure of 1 joule in moving 1 coulomb through it, though at this stage

the concept of potential itself can be introduced only through vague descriptive passages and not as the integral of field strength (work done on a unit charge) in a field first shown to be conservative, as in the traditional sequence. The unit of resistance proceeds logically from these definitions but the next step is to define magnetic flux φ from the induced voltage resulting from unit rate of change of φ. Flux density is then defined as flux per unit area. Now to a person familiar with flux as a rigid mathematical concept arising from Gauss's theorem such a procedure is allowable as a way of establishing a special unit of flux, but a beginner with a spark of critical faculty must feel that he is being asked to take a great deal on trust, for flux is nothing to him but a vague notion suggested by the appearance of iron filings around a loop of wire carrying a current.

A similar procedure introduces field strength (H), which is defined as " a vector along the axis of a long solenoid and of magnitude equal to the ampere-turns per unit length of the solenoid " (page 32). The definition is clearly based on the corollary to Ampère's theorem known as the " Work Law," but this fact is concealed by the authors because they do not permit themselves to refer to the work done on (or by) a unit pole. The pupil is again asked to perform an act of faith while his teachers, who have probably been brought up on the traditional method, can privately refer to the underlying reasons. As Hammond(4) remarks in a similar connection, " It is no kindness on the part of those who have reached a firm foothold to attempt to remove the stepping-stones from those who follow."

Realizing now that the definition of H just given is useful only for uniform fields the authors next give what they call a " generalized definition" applicable to other circuit configurations. This is the rationalized version of the Laplace or Biot-Savart formula

$$dH = \frac{ids \sin \theta}{r^2}$$

for the field strength due to a current element ds. Thus the same authors who have strained at a magnetic pole now swallow a current-element !

Entering the domain of electrostatics we find field strength E defined as the gradient of potential. The definition of induction or flux density is enigmatically given as " a vector whose magnitude is the quotient when the charge displaced across an imaginary small surface perpendicular to the field is divided by the area of the surface and whose direction is the same as that of the field." The explanation preceding the definition (pages 22 and 23) is too diffuse to render the nature of this " displacement " at all clear. In fact, we are once again faced with an idea accessible to the teacher but concealed from the pupil, namely, Maxwell's principle of the displacement current.

Enough has been sketched to illustrate the extreme intellectual looseness of this approach. It can do nothing but harm in the teaching of physics to schoolchildren intending to climb to the higher branches of the subject. It might be suitable for a quick training of the narrower sort, but would be disastrous to the embryo graduate, to whom the avoidance of units conversions is less important than the proper understanding of fundamentals. If non-specialist pupils in grammar and public schools are to receive their impressions of the scientific method from teaching of this kind their respect for science as an intellectual discipline will quickly vanish.

It may be argued that finding fault with one particular teaching sequence, even though it be one with the backing of a committee of experienced science masters, does not prove that it is impossible ever to achieve a wholly satisfactory approach using the new units from the start. This is admitted, but by focusing attention on the central feature of the m.k.s. system, namely, the divorcement of D from E and B from H in free space, the extreme improbability of this desirable achievement can be seen.

The definition of E presents no difficulty in any system of units, but D must be defined as " that vector *whose surface integral* is 4π times the charge enclosed " (supposing an unrationalized system). Such a definition could be said to possess the experimental basis of Faraday's ice-pail experiment, but to proceed from this " integral " basis to the vector D without a preliminary examination of the properties of D is unsound. It might be likened to the definition of the velocity vector in liquid flow as " the number of cubic feet per second per square foot of cross-sectional area," the essential idea of direction being omitted. A " preliminary examination " of D would in this case amount to a return to the traditional method of defining it. The result of the ice-pail experiment can then be predicted, and this separate recourse to experiment avoided.

Similar objections can now be perceived to the procedures of defining H from current and B from induced voltage. In the first case one again attempts to define a vector (H) from a scalar (m.m.f.) and there is the additional objection that the " Work Law," on which the definition is founded, is not a clear-cut experimental result but one deduced from experiment by a complicated

series of arguments. The second case, like the definition of D, is again unsound because it derives a vector from a scalar and because it represents an unnecessary appeal to experiment ; for if B is defined in the traditional manner it is possible to predict the law of electromagnetic induction from Ampère's experiments combined with the principle of energy conservation. Admittedly this course was not open to Faraday, but in a sequence of this kind one cannot impose on oneself all the historical disabilities. One can, however, pick out the most logical and meaningful highway through past events and discoveries as they are revealed in the light of historical perspective.

Thus we see that the teaching method irresistibly suggested by the divorce of the flux-densities from the field strengths in the name of practical convenience can be used only in cases where a logical presentation is not required and where the suggestion of working rules based on plausible discussion will suffice. There is undoubtedly a field for instruction of this kind, but the invasion of our grammar and public schools by such teaching would seriously prejudice the chances of those pupils intending to proceed to a degree course in physics. Speaking as a university teacher concerned with freshmen, I should prefer my students to come up to the university with a modest knowledge of physics thoroughly understood in a logical way and capable of being applied in a mathematical manner. A far wider knowledge of a diffuse and descriptive kind is not only useless but positively harmful.

THE AVOIDANCE OF THE MAGNETIC POLE CONCEPT

This peculiarity of many teaching sequences is not indissolubly linked with the m.k.s. system though it is in fact a customary accompaniment. It also characterizes many attempts to improve upon the traditional approach even when m.k.s. units are not specifically mentioned. For example, Tricker[5] seeks to accelerate school physics teaching by cutting both electrostatics and magnetostatics out of the course. The mutual forces between current circuits form the starting point in this method which is thus claimed to represent a return to Ampère's treatment of the problem. However, the introduction of the ordinary field vectors, which take their origin from the idea of the magnetic pole and have little significance without it, then seems very artificial and the method, as given, ends in confusing B and H and fails in the treatment of permeable media. In passing we may note the recent attempts at a thorough-going elimination of field concepts in the *New Electrodynamics*[6] of P. Moon and D. E. Spencer. This is the logical conclusion of Tricker's search, though many difficulties have yet to be overcome, notably the treatment of permeable media.

The elimination of the magnetic pole from teaching methods fails to equip the student for dealing with magnetic media, particularly permanent magnets ; this may easily be seen by attempting to explain the contrary directions of B and H in a permanent magnet without recourse to the pole concept. But the strongest argument against the elimination of the pole is that it prevents a meaningful discussion and definition of field-strength, dipoles, magnetic potential, magnetomotive force, magnetization and other important ideas.

RATIONALIZATION

This can be applied to any system of units and has for its object the elimination of the factor 4π from advanced equations by inserting it in the elementary ones. The undersirability of putting even a small additional difficulty in the way of the beginner has already been mentioned. There are also some curious side-effects of rationalization as applied to the m.k.s. system. One of these is the actual *identification* of the units of totally different quantities ; for example, the measurement of H in amperes per metre or electrostatic flux in coulombs. This feature is actually claimed as an advantage, as though the management of a large family were simplified by giving the same name to several children ! As an instance of the confusion arising from the unit of H one has only to reflect that in the magnetic circuit of a choke with an air-gap there is at no point a field strength equal to the ampere-turns per metre of magnetic path. Attempts to elucidate matters by recourse to analogies with potential gradients lead to such conundrums as " What is the value of the ampere-turns at this point ? "

An oft-quoted argument (due to Heaviside) in favour of rationalization is that it simplifies the relationships for the one-dimensional field (that of a parallel-plate condenser) at the expense of the three-dimensional one (that of a point charge). This would be commendable only if all charge-distributions could be regarded for integration purposes as built up from infinite plane charges. Very few can actually be so regarded, but on the other hand any distribution can be treated as though composed of numerous point charges, to which the inverse-square law can be applied. Let us then, keep this law simple,

CONVERSION COURSE

How can we combine the logically satisfying traditional approach to electricity and magnetism with the practical convenience of the m.k.s. units ? We are driven to the conclusion that the only satisfactory way is to preserve and improve the traditional teaching sequence, drawing on modern developments in insulators and permanent-magnet materials and introducing m.k.s. units only after a firm and logical foundation has been laid. The student must be capable of expressing and using his knowledge in mathematical form before the convenient fictions of the m.k.s. system are introduced. It is to be hoped that improvements in the teaching of mathematics and, in particular the widening of the scope of what is called " applied mathematics " to cover a great deal more than mechanics, will in future enable this stage in the student's development to be reached at an earlier age than at present. It might then be possible to take the student up to Maxwell's equations and let him see the almost miraculous revelation of the inner meaning of the prosaic units-ratio c as Maxwell must have seen it. The student brought up on m.k.s. units is denied this experience because the velocity of light has already crept in through the back door disguised as the " permittivity of free space " and what should be a miracle becomes merely an elaborate trick.

It is not necessary, however, to delay the introduction of m.k.s. units to the post-Maxwell stage. They can be introduced as soon as the fundamentals have been mastered in a mathematical form. A " conversion course " based on the foundations already laid would give the student the advantage of a logical background to his knowledge as well as the convenience of the m.k.s. system with its freedom from units conversions.

But what does this " freedom " amount to ? All the tables of physical and chemical constants are in c.g.s. units and likely to remain so ; and if you ask a manufacturer for data on a magnetic material you will probably receive a graph showing " lines per square inch (peak) " plotted against " ampere turns per inch (r.m.s.) ! "

REFERENCES

1. Macfadyen, K. A. " The m.k.s. system of units in schools." *School Science Review*, **35**, 371 (1954).
2. Bleaney and Bleaney. *Electricity & Magnetism* (Oxford), (1957).
3. *The Teaching of Electricity*. Report of the Science Masters' Association (Murray).
4. Hammond, P. " A short modern review of fundamental electromagnetic theory." *Proc. I.E.E.*, **101**, Part I, 147 (1954).
5. Tricker, R. A. R. " On the Teaching of Electricity." *School Science Review*, **35**, 378 (1954) and later numbers.
6. Moon, P., and Spencer, D. E. " A new electrodynamics." *J. Frank. Inst.*, **257**, 369 (1954).

Reviews of Books

REASON AND CHANCE IN SCIENTIFIC DISCOVERY

By R. Taton (translated by A. J. Pomerans)

London : Hutchinsons Ltd. Pp. 171. Price 30s.

The value of this book lies not only in its theme, as indicated by the title, but more particularly in the position which the author takes up with regard to the epistemology and psychology of the facts of discovery. The usual tendency in dealing with the subject is nearly always towards over-simplification. Here, each major advance is seen as the outcome of a chain of events, whether it be in astronomy, biology, chemistry, instrumental techniques, mathematics, medicine or physics. The predominant factors may be historical, social, personal, but in essence they are aesthetic. The mind of the born discoverer is in advance of its time in a capacity to apprehend hitherto unknown harmonies and synthetic elements.

To British readers, the balance of power may seem a little tipped in favour of Europe, especially France. This is no bad thing if it illustrates how variable the density of invention has been at various epochs. Genius is certainly not the prerogative of any one race. But the *geistesblitz*, or flash of intuition, is capricious and seems to strike when people of exceptional ability are off duty. And this train of thought leads the author to utter a word of warning—very wisely—against the dangers inherent in the fashionable team-work of to-day. The really valuable scientist must be free to break out on his own, however inconvenient it may be for planned researches and useful targets. Effective as organization is, it may become the foe of creativeness.

The well-known coincidences of discovery are discussed well and with freshness—analytical geometry (Descartes and Fermat), the calculus (Newton and Leibnitz), non-Euclidean geometry (Lobatschewsky, Bolyai, Gauss) and elliptic functions (Abel and Jacobi). It would seem that

periodically a species of logical pressure develops, such that, concentrated on two or more minds simultaneously, the valves are bound to lift, and discovery follows. Conversely, a "near-miss" is occasionally recorded, as when Helmholtz invented the ophthalmoscope, though Brucke could equally well have done so at the same moment.

It may well be that we are not without witness or excitement in our own day. For example, as recently as November 9, 1957, the discovery of a proof of Fermat's last theorem (1637) was reported from Lahore, after some 320 years of attempts. Only time will show whether this one will achieve universal acceptance. Not long before, there was a false alarm, as indeed sounded in 1845, when a supposed solution was negatived by Dirichlet. And thus, the fascinating story of discovery goes on, so well treated in this book.

It only remains to add that the translation is adequate and idiomatic. If only time would allow, the six-forms of schools, and many undergraduates, would delight in it.

F. I. G. Rawlins.

THERMODYNAMICS AND STATISTICAL MECHANICS

By A. H. Wilson

Cambridge University Press. Pp. xv + 495. Price 50s.

This is an advanced text book written by a mathematician primarily for theoretical physicists, and is a worthy successor to the series of standard text books of Cambridge University Press. It is a matter of some astonishment to the reviewer that the author, who leads an extremely busy life as Director of a very important industrial research laboratory, has been able to find the time to prepare a text involving so much detailed mathematics, and showing every sign not only of knowing the literature well, but of having digested it so as to produce a coherent and logical story. Although the book is written for theoretical physicists, the mathematical concepts involved are rarely more difficult than those available to a well trained practical physicist, the complications arising mainly from the complexity of the formulae which results from the details into which people have gone to develop a satisfactory model as, for example, in dealing with crystalline solids.

The first three chapters derive the fundamental results of thermodynamics by the traditional methods, but include also some examination of the logical difficulties concerning temperature and quantity of heat, while the fourth chapter gives Caratheodory's method of proving Carnot's theorem without using Carnot's cycle. The treatment is, however, prevented from losing all contact with physical reality by using illustrations from the properties of gases. Chapter 5 plunges quickly into statistical mechanics using Schrodinger's equation to express the wave functions, while Chapter 6 applies statistical mechanics to specific heat of gases, crystalline solids, Fermi-Dirac and Einstein-Bose systems and radiation, although under radiation, Planck's use of statistical mechanics is regarded as being superseded by more direct methods. The treatment of the third law of thermodynamics in Chapter 7 is based on Simon's work in 1930, as there has been no major change in its status since then. The cases of gases where the residual entropy of the solid is not zero at absolute zero temperature are discussed in detail. Chapter 8 deals with the equations of state, the critical point, and the thermodynamic functions of an imperfect gas, and Chapter 9 with the equilibrium of a single substance between difference sizes, examples being the graphite diamond transformation for carbon and the solid liquid gaseous transformation for hydrogen and helium. In Chapter 10 the consequences of applying the laws of thermodynamics to systems with electrostatic and magnetostatic fields and to superconductivity are worked out, and statistical mechanics is applied to polar substances.

The last four chapters consist of more detailed applications of thermodynamics and statistical mechanics to gas mixtures and chemical reactions, solutions, the elasticity of rubber and superlattices in alloys.

In conclusion, it can be said that the book can be strongly recommended to anyone who wishes to be brought up to date on the mathematical application of thermodynamics and statistical mechanics to any of the problems mentioned in this summary of the chapters. It does, however, confirm the conclusion that choice of the word "thermodynamics" in the first place was unfortunate, as it implies that time appears as a variable, whereas all the systems considered here are concerned with those infinitesimal changes which are normally described under the heading of statics.

M. W. Thring.

EXPERIMENTAL CRYSTAL PHYSICS

By W. A. Wooster

Oxford : Clarendon Press. Pp. viii + 115. Price 18s.

Crystal physics is a study that is too often neglected in university physics departments. As

Dr. Wooster says, it " is not an easy subject, and there are many pitfalls for the ignorant. A sound knowledge is hardly to be gained from theoretical studies alone." We are already in his debt for his textbook *Crystal Physics*, and now he gives us this little book of descriptions of experiments suitable for undergraduate practical classes.

As might be expected, the selection of measurements is governed to some extent by ease rather than interest, and in general the amount of space devoted to a property varies inversely with the complexity of the tensor expressing it. Properties involving second-order tensors receive 63 pages, involving third-order tensors 19 pages, and involving fourth-order tensors 8 pages. Plasticity and pyroelectricity, whose tensor nature is not discussed, get 7 pages each.

The plan adopted for each experiment—there are about 30 of them—is simple. The necessary apparatus is described, a little theory is given, and one or two actual sets of measurements are worked out. An appendix describes a method of growing single-crystal wires of cadmium, needed for experiments on plastic deformation. There is a bibliography and a list of original papers ; the latter range from Fresnel (1822) to Laval (1951). For some physical properties one would have welcomed more specific references to the bibliography. Within its self-imposed limits there is little to criticize about the book, and there is now no excuse for neglect of experimental crystal physics in undergraduate teaching, especially as an address is given from which the necessary apparatus can be obtained.

A. J. C. Wilson.

ELECTROMAGNETISM AND RELATIVITY

By E. G. Cullwick

London : Longmans, Green & Co. Pp. xxiii + 299. Price 63s.

Our degree and equivalent course syllabuses are steadily becoming more overcrowded as knowledge expands and it is, one supposes, almost inevitable that some topics will be omitted altogether or be given only the briefest mention. One such topic is the electrodynamics of moving media. Most physicists and engineers probably get as far as formulating the law of induction sufficiently for the ordinary problems of motors and generators, and leave it at that. When suddenly presented with such puzzles as the rotating cylindrical magnet we realize how uncertain is our knowledge, or how profound is our ignorance, and we resolve to do something about it. Usually the resolve is soon forgotten under the pressure of more urgent matters.

Now Professor Cullwick has come to our rescue with this book on Electromagnetism and Relativity. The special theory of relativity is introduced in Chapter 5 primarily in order to discuss the relativistic transformation of Maxwell's equations in Chapter 6 and subsequent applications. He does, however, digress from his main purpose to discuss the " clock paradox " which has featured in recent issues of the *Bulletin* and in other journals, coming down strongly on the side of Professor Dingle.

The main purpose of the book is the discussion of moving media and induction and a first order non-relativistic theory is developed which gives the correct answers to the rotating magnet type of problem when the velocity is very much smaller than the velocity of light. This occupies Parts I and II, about two-thirds of the book. A short Part III gives two examples of second order e.m.f.s in moving circuits where the relativistic theory is necessary, and Part IV considers electromagnetic energy and momentum.

How often have teachers developed the equations of motion of a rigid body, with an uneasy feeling at the back of their minds that some cases of electromagnetic forces might not fit in very easily with their story about the internal forces cancelling because the action and reaction act with equal magnitudes, in opposite senses, along the same lines.

Here in chapter 17 they will find the very problem discussed, and will find Newton's third law vindicated provided momentum is associated with moving energy and the mass-energy relation $W = mc^2$ of relativity theory is admitted.

Many other interesting questions are discussed, the later chapters drawing on original work of the author on electron inertia in a current circuit and in a super-conducting sphere published in I.E.E. monographs, and the book can be recommended to any physicist interested in these fascinating problems. The book is not, however, easy reading. The mathematics used is not difficult. No more is required than a knowledge of vector analysis, the main formulae of which are collected in an appendix, but the number of equations per page, which reaches a peak of 69 numbered equations in the nine pages of chapter 7, is such that one is in grave danger of losing the physics altogether in a multitude of equations. It is a book for reference, or to work through with pencil and paper, rather than just to read.

A. W. Gillies.

PHYSICAL CHEMISTRY

By E. A. Moelwyn-Hughes

London : Pergamon Press. Pp. vii + 1295. Price 70s.

A very useful book by Dr. Moelwyn-Hughes, covering certain parts of the subject, appeared in 1940 (*Physical Chemistry : an Introduction*, Cambridge University Press). The present work, expanded to cover most of the field generally dealt with in text-books of Physical Chemistry, is presented as an up-to-date and comprehensive text-book for advanced students of chemistry. It is indeed a formidable work in which the basic concepts of physical chemistry are expounded with full mathematical rigour. The treatment is, however, relieved by the lucid and invigorating introductory paragraphs that occur in most chapters and wherever a new topic or concept is introduced. The clarity of expression achieved by the author in dealing with abstruse matters is a remarkable, and indeed an extremely rare gift.

The plan of the book is excellent : after careful consideration of the experimental foundations and mathematical formulation of kinetic-molecular theory and quantum theory, of chemical thermodynamics and of the study of molecular structure, the various states of matter are treated, as far as possible, from the viewpoint of statistical mechanics. Chapters on the crystalline, gaseous, metallic, liquid, dissolved, ionic, and interfacial states are followed by a discussion of chemical equilibria and reaction kinetics in homogeneous and heterogeneous systems.

This book has been produced over a period of many years, and the immense experience and scholarly effort of the author are evident. However, many of the chapters were written some time ago, and a certain unevenness in the treatment must be noted. For example, in the chapter on kinetics of reactions in gaseous systems only six references of sixty-eight refer to publications later than 1936. Later work has clearly influenced our understanding of the mechanism of several reactions which are discussed (the decomposition of N_2O_5 to mention only one instance). New experimental techniques and current interests in this and other fields, such as the study of molecular structure, should perhaps have received more emphasis.

It is to be hoped that more material of this kind may be incorporated in future editions of this book. At present it provides a systematic and comprehensive presentation of the foundations of the subject and as such should prove invaluable to honours students and others specializing in Physical Chemistry. The examples provided at the end of most chapters are a useful feature of the book, which is well produced and reasonably priced.

E. Gelles
J. Monteath Robertson

IONIZATION AND BREAKDOWN IN GASES

By F. Llewellyn-Jones

Methuen Monograph on Physical subjects. Pp. 176. Price 18s.

For many years teachers and students have used Methuen monographs as convenient sources of useful and authoritative information. They will wish to add this volume to their collection.

It is in no sense a rehash of earlier text-books on gaseous ionization. Thus the author is not here concerned with the maintenance of electrical discharges already established, such as the glow or the arc. In a short chapter on fundamental processes of ionization and de-ionization the reader is referred to other works for more detailed information in these fields. The monograph deals with the subject of gaseous breakdown, considered—to use his own words—in two aspects ; first the elucidation of the mechanism setting the criterion which must be satisfied before breakdown is at all possible ; and secondly the mechanism by which an ionization current can increase when once the breakdown criterion is satisfied.

The early development of the subject by Townsend forms the basis of the work, but the treatment is brought up to date and much recent experimental data included, in a form not previously readily available to many probable readers.

There are many points of interest to be found in its pages in attractive style. A good collection of references is also included, though J. J. and G. P. Thomson never spelt their names with a "p" !

A. M. Tyndall.

TRANSISTOR ELECTRONICS

By D. Dewitt and A. L. Rossoff

New York : McGraw-Hill Publishing Inc. ; London : McGraw-Hill Publishing Co. Pp. xii + 381. Price 60s.

This book represents a very valuable addition to the literature on semi-conductor devices and their applications. The authors, faced with the usual problem of where to start, have chosen to err on the safe side—they begin with Bohr atom. From there they attempt to establish in one chapter a background of semiconductor physics

comprehensible to the circuit engineer. The reviewer is inclined to doubt the advisability of such drastic telescoping of fundamental exposition which is becoming increasingly popular with authors in this field.

After the first chapter, however, the authors are on much safer ground. They give an orthodox treatment of *p-n* junctions (the " idealized " diode characteristic of Fig. 2.2 would fail to pass any specification) and a brief description of junction transistors. From here onwards the standard of presentation becomes very high. A chapter on low-frequency small-signal operation is followed by an excellent exposition of transistor static characteristics containing a comprehensive discussion of temperature stabilization and compensation. The high-frequency equivalent circuit is developed from physical principles with commendable paucity of mathematical formulae. This is followed by discussion of a wide range of topics of practical interest : transient and high-frequency amplification, large-signal transients and switching, mixers and demodulators, transistor switching circuits and radio receivers. Special structures (e.g. drift- and point-contact transistors) are briefly treated and one chapter is devoted to transistor noise. The book concludes with several pages of problems and four pages of reasonably up-to-date bibliography.

The treatment throughout is matter-of-fact and directed towards the understanding of concrete situations likely to arise in practice. The authors may be excused for not introducing any numerical parameters of commercially available transistors into their treatment. The typographical presentation is excellent and the reviewer has found very few mistakes and errors.

This book may be safely recommended as a very good value for its price to all who require a serious introduction into the subject of transistor electronics.

A. K. Jonscher.

ELECTRONIC DESIGNER'S HANDBOOK

By R. W. Landee, D. C. Davis and A. P. Albrecht

London : McGraw-Hill Publishing Co. Pp. xii + 1014 + 20. Price 128s.

This book is intended for students and practising engineers since it emphasizes design problems. An attempt is made to give a much more theoretical background than in more usual design handbooks, and indeed the practical problems often seem to recede into the background. The worked examples are very useful and for these reasons students might be expected to have more interest in the work than would be the case with most handbooks on design. The book is extremely comprehensive, as would be expected from its length and price, and a vast amount of detailed work is covered.

There are sections on vacuum tubes and transistors, voltage and power amplifiers, modulation, oscillators, receivers and multi-vibrators. There is a group of sections on special circuits, for example, trigger circuits and saw tooth generators, followed by sections on inductively coupled circuits, transformers and chokes, power supplies, filters, attenuators and principles of feedback. There is a very useful account of computer and servo - mechanism techniques. Finally, transmission lines, antennas, wave form analysis and network analysis are dealt with.

I have listed the sections in the order they appear, and it will be seen that this is not necessarily the best arrangement, even for those students who could profitably use this book in their studies.

J. D. Craggs.

ELEMENTARY THEORY OF ANGULAR MOMENTUM

By M. E. Rose

London : Chapman & Hall Ltd. Pp. x + 248. Price 80s.

The theory of angular momentum has long been of importance in spectroscopy, and those interested in the subject twenty-five years ago had to find their way rather painfully through highly formal textbooks and papers. The theory has lately become even more important mainly because of improvements in experimental techniques for measuring angular distributions or angular correlations in nuclear physics, and because of problems in low-temperature studies and in microwave spectroscopy involving static moments coupled to fields arising from surrounding charges. But present-day students are more fortunate than their predecessors in having such a clear book as this under review to introduce them to the theory. The knowledge of quantum mechanics acquired by any competent graduate should be sufficient to its complete understanding.

After a review of basic principles, the Clebsch-Gordan (or Wigner) coefficients for the coupling of two angular momenta are introduced with simple examples. Particularly lucid and useful is the chapter devoted to the study of the transformation properties of the angular momentum

eigenfunctions under rotations, where little loss of generality is caused by the avoidance of group theory, and the power of simple inductive reasoning is amply demonstrated.

When three angular momenta have to be compounded, and a representation is desired in which the square and z-component of the total angular momentum are diagonal, one has to compound first any two of the angular momenta into an intermediate one, and then compound this intermediate angular momentum with the third member of the original set. Clearly this may be done in three ways, and two representations characterized by two different intermediate angular momenta are related by a unitary transformation, the elements of which are proportional to the Racah coefficients. These coefficients are of great importance in many applications and their properties are adequately discussed.

The second part of the book is devoted to applications, particularly to multipole fields, static interactions, oriented nuclei and angular distributions in nuclear reactions. Tables of the Clebsch-Gordan and Racah coefficients are given in an appendix, but they might usefully have been more extensive. The book is well printed and very few mistakes have been noticed. Here and there its origin as lecture notes has not been completely obliterated. Dr. Rose is to be warmly congratulated for having succeeded so admirably in bringing a difficult subject within the grasp of a wide circle of physicists.

L. PINCHERLE.

CLOUD STUDY (A Pictorial Guide)

By F. H. Ludlam and R. S. Scorer

London : John Murray. Pp. 80. Price 12s. 6d.

What Sir Napier Shaw called Pageantry in the Sky has had an irresistible appeal to many artists and scientists ; in particular, meteorologists who have also been keen photographers have done much to provide a permanent record of scenes from the ever-changing pageant. The cloud photographs taken by G. A. Clarke and C. J. P. Cave are world-famous, and their collections have been left to the Royal Meteorological Society. In addition many interesting cloud photographs are published in the Society's magazine *Weather*. *Cloud Study* has been produced under the auspices of the Society and the Authors have been able to draw on the Society's collections of photographs ; they have also included some of their own. The resulting selection of 73 photographs, with explanatory notes, form the bulk of the book, but there is also a short but useful introduction on the formation and dissipation of clouds. Although many types of cloud are illustrated, the book is not an atlas of cloud types, but is intended rather to illustrate the physical processes of formation. The laminated wave-cloud like a pile of flying saucers (No. 46), and the mother-of-pearl cloud (No. 54) are particularly noteworthy. The book is very well produced and should form a useful addition to the meteorologist's library.

J. S. FORREST.

Group News

Non-Destructive Testing Group

The Non-Destructive Testing Group held its first social evening on January 17, when a total of 65 members and their ladies assembled for dinner at the Criterion in Piccadilly.

The dinner was followed by an illustrated talk given by Professor C. B. Allsopp of Guy's Hospital Medical School. The title of his talk " Some Applications of Physics in the Investigation of Crime " had to be carefully chosen so as not to imply that any cases of disreputable conduct in the profession were to be disclosed, nor that the subject had any veiled implications associated with the invitation being extended to members' ladies !

Professor Allsopp illustrated, in a commendably lucid way, how simple physical techniques such as photography and spectroscopy had been applied with success in providing scientific evidence in a number of specific criminal investigations.

Although the subject matter of the first few slides made the organizers appreciative of the fact that the talk had been arranged to follow the dinner rather than precede it, the evening's arrangements proved to be highly successful and should encourage the Group Committee to organize similar occasions in the future.

R. S. SHARPE.

News of Members

FELLOWS

C. E. Challice has been appointed Assistant Professor of Physics at the University of Alberta, Canada.

A. Charlesby has recently been appointed Professor of Nuclear Physics at the Royal Military College of Science, Shrivenham.

D. G. Drummond is now Electron Microscopist at the University of Sydney, Australia.

A. J. Ede is now Head of the Heat Division of the Mechanical Engineering Research Laboratory, Glasgow.

J. V. Hughes is with the Republic Aviation Corporation, Farmingdale, U.S.A.

B. B. Ray has been appointed Deputy Chief Engineer of Nangal Fertilizers and Chemicals, Punjab, India.

R. S. Silver is now General Manager of the Technical Division of G. & J. Weir Ltd., Cathcart, Glasgow.

ASSOCIATES

W. Bosley is Head of Physics Department, Huddersfield Technical College.

A. Charnley has been appointed Senior Science Master at St. Mary's College, Blackburn.

E. R. Collins is now working in the Physics Department of Auckland University, New Zealand.

G. W. G. Court is now with the Civil Aviation Administration Air Department, Wellington, New Zealand.

K. J. Close has been appointed Senior Lecturer in the Physics Department at The Polytechnic, Regent Street, London.

G. E. Darwin is now working with Babcock & Wilcox Ltd., in the Atomic Energy Department.

D. A. Dyer has taken up a post in the Research Department of British Nylon Spinners Ltd., Pontypool.

R. W. Fearn has taken up a new appointment with Biddle Holdings Ltd., London.

C. M. Gateley is now Adviser for Further Education in Liverpool.

T. K. Jones has been appointed Technical Officer in the Research Department of Imperial Chemical Industries Ltd., Billingham.

N. Kasinathan is Assistant Director of the Telecommunication Research Centre, New Delhi, India.

J. R. A. Lakey is now working in the Atomic Energy Division of the General Electric Co. Ltd., Erith.

Yung Kuo Lim has joined the staff of the Physics Department of the University of Malaya.

T. W. Lindop has been appointed Head of the Physics Research Laboratory of the Morgan Crucible Co. London.

B. R. Malcolm has been appointed Lecturer in Biophysics at the University of Edinburgh.

D. J. R. Martin is employed as a Scientist by the National Coal Board at the Mining Research Establishment, Isleworth.

C. D. Mee is now working as a Senior Physicist at C.B.S. Laboratories, New York, U.S.A.

A. J. Mortlock is a Senior Scientific Officer in the Metallurgy Department of the Atomic Energy Research Establishment at Harwell.

Thong Saw Pak has joined the Chinese Academy of Sciences in Peking as a Research Member.

A. V. Parker has joined the staff of the Operations Reactor Group of the Atomic Energy Authority, Dounreay.

D. A. E. Roberts is a Microwave Engineer with Ragtheon Manufacturing Co., U.S.A.

S. Scregg is at the Royal Aircraft Establishment, Farnborough.

T. R. Stretton is working with the British Joint Services Mission, Washington, U.S.A.

P. B. Wallis has joined Henry Wiggin & Co. Ltd., Hereford, as an Engineer-in-Charge of Mechanical Testing.

B. H. Woodcock is in the Electronics Laboratory of Hilger & Watts Ltd., London.

GRADUATES

A. A. Balchin has joined the Crystal Analysis Group of The General Electric Co. Ltd., Wembley.

B. Eric is a Physicist in the Research Department of Bexford Ltd., Brantham, Nr. Manningtree.

A. H. Flint is with Avro Aircraft Co. Ltd., Ontario, Canada.

W. F. Hunter is attached to Admiralty Research Laboratory, Teddington.

K. Mentzer is in the Central Research Laboratories of Richard Thomas & Baldwins Ltd.

T. W. Morrison has taken up an appointment with the Triad Oil Co. Ltd., Alberta, Canada.

E. A. Ryder has joined the staff of Hawker Siddeley Nuclear Power Co. Ltd.

D. J. Sansom is Assistant Physics Master at Rochdale Grammar School for Boys.

W. A. Smith is a Scientific Officer at Atomic Energy Authority, Foulness.

Veronica M. Spiers is with Aeon Laboratories, Englefield Green.

Y. S. Sunthankar is a Development Engineer at the British Telecommunication Research Ltd., Taplow.

D. A. Walker is employed by Rolls Royce Ltd., Derby.

K. Wilkins is employed as a Physicist in the Atomic Power Division of the English Electric Co. Ltd., Whetstone.

Forthcoming Institute Meetings

Feb. 21 Applied Spectroscopy Group — At the Institute's House, 3 p.m.

A Meeting on

" X-ray Fluorescence "

The program has been circulated to Group members and is available to others on application to the Institute

March 3 Scottish Branch

In the Department of Natural Philosophy, University of Edinburgh, 7.15 p.m.

" An approach to the limits of infra-red detection "

PROFESSOR R. V. JONES, F.Inst.P., F.R.S.E.
(*University of Aberdeen*)

March 4 Scottish Branch

In the Department of Natural Philosophy, University of Glasgow, 7.15 p.m.

" An approach to the limits of infra-red detection "

PROFESSOR R. V. JONES, F.Inst.P., F.R.S.E.
(*University of Aberdeen*)

March 5 Education Group — At the Institute's House, 6 p.m. Tea 5.30 p.m.

Group Annual General Meeting (at 5.15 p.m.)

followed by

" The Spinning Galaxy—a history in co-operation between sciences "

DR. MARTIN JOHNSON, F.Inst.P.
(*University of Birmingham*)

March 7 Liverpool and North Wales Branch

In the Department of Electrical Engineering, University of Liverpool, 7 p.m. Tea 6.30 p.m.

" High Resolution Mass Spectrometry "

MR. J. H. BEYNON, A.Inst.P.
(*Imperial Chemical Industries, Dyestuffs Division*)

March 12 Midland Branch — At the Birmingham Exchange and Engineering Centre, 7 p.m.

" Applications of High Speed Photography "

MR. E. W. WALKER
(*Atomic Weapons Research Establishment, Aldermaston*)

March 14 Non-Destructive Testing Group At the Institute's House, 6 p.m. Tea 5.30 p.m.

" Electron Probe Methods "

MR. P. DUNCOMB, Grad.Inst.P.
(*University of Cambridge*)

March 14 South Western Branch In the Department of Physics, University of Bristol, 7 p.m.

" The Birth of the Nuclear Atom "

PROFESSOR E. N. DA C. ANDRADE, F.Inst.P., F.R.S.

March 14 South Wales Branch

In the Department of Physics, University College of South Wales and Monmouthshire, Cardiff, 5.15 p.m.

" The Cybernetic Approach to Mentality and Society "

DR. W. GREY WALTER
(*Burden Neurological Institute*)

March 14 Manchester and District Branch

In the Bragg Lecture Theatre, University of Manchester, 6.45 p.m.

" The Antiquity of Technology "

PROFESSOR P. M. S. BLACKETT, F.R.S.
(*Imperial College of Science and Technology, London*)

March 17 Scottish Branch

In the Department of Natural Philosophy, University of Edinburgh, 7.15 p.m.

" The Liquid State "

PROFESSOR J. D. BERNAL, F.Inst.P., F.R.S.
(*Birkbeck College, London*)

March 18 Scottish Branch

In the Department of Natural Philosophy, University of Glasgow, 7.15 p.m.

" The Structure and Development of the Planets "

PROFESSOR J. D. BERNAL, F.Inst.P., F.R.S.
(*Birkbeck College, London*)

March 18 Electronics Group At the Institute's House, 5.30 p.m. Tea 5 p.m.

Group Annual General Meeting

followed by

" Microwave Ferrites "

MR. L. A. THOMAS, F.Inst.P.
(*Research Laboratories, The General Electric Co. Ltd., Wembley*)

March 19 Yorkshire Branch In the Department of Physics, University of Leeds, 5.15 p.m.

Branch Annual General Meeting

Followed at approximately 5.30 p.m. by

" Research by Rockets and Satellites "

DR. R. L. F. BOYD
(*University College, London*)

Vol. 9, February, 1958

The Institute's Journals

PRINCIPAL CONTENTS OF THE FEBRUARY, 1958, ISSUES

Journal of Scientific Instruments: Volume 35, No. 2

ORIGINAL CONTRIBUTIONS.

New types of recording differential thermobalances. By P. L. Waters.

The paper describes two types of thermobalances which automatically record both the differential and cumulative weight losses during pyrolysis of samples. In both balance systems displacement of the balance beam due to changes in the weight of sample is converted into an electrical signal ; the amplified signal operates the servo-mechanism which applies the counterbalancing force at the necessary rate. However, the servo-mechanisms differ in the two types. In one, an analytical balance is adapted so that the sample is counterbalanced by the suspended electrode of a silver coulometer ; the controlling current passing through the cell gives a measure of the rate at which the sample loses weight. In the other, a servo-motor rotates the head of a torsion balance to maintain equilibrium ; the rate of weight loss is proportional to the speed of the motor and to the voltage applied to it. Alternative control circuits are mentioned. The present torsion-type differential thermobalance can record total weight changes up to 0·5 g at a maximum rate of 30 mg per minute. The cumulative change in weight is registered to the nearest 0·1 mg on the dial counters and 1 mg on the recorder chart ; the differential weight change can be read to dial counters and 1 mg on the recorder chart ; the differential weight change can be read to within 0·2 mg per minute. As the differential weight loss is sensitive to variations in heating rate, a linear-rate controller capable of high accuracy was specially designed for use with the thermobalance.

A linear, unidirectional anemometer of rapid response. By R. J. Taylor, A.Inst.P.

A heated wire dissipating constant power causes temperature changes in the air moving past it which vary approximately inversely as the wind speed. These temperature changes are detected by a thermometric bridge and, by means of a circuit with feedback control, an electrical signal is constructed which is linearly related to the velocity. The resulting anemometer is sensitive only to the normal velocity component and, by combining two such anemometers, changes in sign of this component can be accommodated. Four fine wires (0·0005 in. tungsten or nickel) are used but they can be replaced if damaged without affecting the calibration. The time constant of the instrument is about 0·3 s at a wind speed of 0·5 ms^{-1} and decreases somewhat at higher speeds.

A magnetic gauge utilizing the magnetron effect. By W. Fulop, A.Inst.P.

The cut-off region of a magnetron diode is shown to be an accurate, though relative measure of the magnetic field. This magnetron effect is utilized to calibrate a sub-miniature diode to serve as fluxmeter. Only simple ancillary apparatus is required and accuracies greater than 1% are easily attainable. Conditions which such a fluxmeter has to fulfil for satisfactory operation are stated, and experiments prove these to be met.

A high-resolution grating spectrometer for the infra-red region. By M. A. Ford, W. C. Price, F.Inst.P., and G. R. Wilkinson.

A grating spectrometer designed on an Ebert mounting has been constructed which, with suitable photoconductive cells and a 6 × 6 in. N.P.L. grating, gives a resolution of 0·1 cm^{-1} in the range 6000 to 1,700 cm^{-1}. It covers the region 600 to 10,000 cm^{-1} with a single grating and is as simple to operate as a conventional prism spectrometer. It is intended as a high resolution general purpose instrument which will give a performance an order of magnitude better than that of a prism instrument over the main spectral range.

Modifications to a travelling microscope used for measuring X-ray powder photographs. By W. E. Armstrong and R. I. Davis.

A travelling microscope has been adapted for measuring powder photographs. The cross-hairs in the microscope eyepiece were removed and the reference mark was obtained from a light spot thrown on the photograph from a projector clamped to the barrel of the microscope. Cross hairs seen in silhouette tend to obscure faint lines on the photograph and prevent their measurement. The light spot eliminates this effect, allows change of magnification for measuring different lines without moving the reference mark, eliminates parallax and allows the use of a binocular eyepiece. These features reduce eye strain by measuring a photograph and improve the accuracy of measurement of faint or diffuse lines. The photograph is illuminated by short fluorescent tube, the light of which is cooler and " harder " in quality than that of filament lamps. Means are described of adjusting the light intensity of the tube over a wide range.

An oxidizing atmosphere furnace for use with an X-ray diffractometer. By S. W. Kennedy and L. D. Calvert.

A resistance furnace assembly to fit the Norelco diffractometer is described. It makes possible the investigation of rigid specimens or powders in controlled atmospheres or vacuum.

The recording of pressure distributions in porous media during fluid flow experiments. By T. O'Donnell, D. H. Edwards, N. Collis-George and E. G. Youngs, Grad.Inst.P.

A null-point method is described of recording in a short time interval pressure distribution in a porous medium

during fluid flow experiments. Small cells, buried at numerous points in the porous material, measure the pressure distribution which is recorded in a separate laboratory.

A simple method of monitoring ultra-violet light. By C. K. Coogan.

A simple monitor has been developed for indicating the progress of solarization of the walls of low-pressure mercury discharge tubes. The intensity of the Hg 5461 Å radiation is compared with the green emission from a phosphor excited by Hg 2537 Å radiation. An intensity match of these two greens can be arranged to occur when the solarization has reached a predetermined point. Other applications of the principle are discussed.

A laboratory electron bombardment furnace. By P. G. England and H. N. Jones.

A furnace is described in which small ingots (approximately $3 \times \frac{1}{2} \times \frac{1}{4}$ in.) of metal can be melted on a water-cooled copper hearth under a high vacuum (less than 10^{-4} mm of mercury). The charge is heated by bombardment with a stream of electrons emitted from a tungsten filament suspended above the charge. A d.c. potential of up to 10 kV applied between the hearth and the filament is used to accelerate the electrons. The use of such a furnace for purifying niobium and melting high purity uranium is described.

A combined liquid nitrogen cryostat, furnace and liquid helium bath. By Miss M. J. Stubbs and M. W. Thompson.

An apparatus is described in which a liquid nitrogen cryostat and a furnace were associated for annealing specimens at temperatures between −196°C and 200°C. Provision was made for transferring the specimens to liquid helium without removing them from the apparatus.

British Journal of Applied Physics: Volume 9, No. 2

SPECIAL ARTICLE

Electroluminescence. By S. T. Henderson, F.Inst.P.

An account is given of the present state of field-controlled luminescence, with references to the earlier experiments using additional forms of excitation, and to carrier injection luminescence. Intrinsic electroluminescence is dealt with at greater length, the main aspects considered being the phosphor, the voltage against brightness relation, and emission wave-forms. Theoretical discussions of the process and practical applications are reviewed.

ORIGINAL CONTRIBUTIONS

The thermal conductivity of nitrogen and argon in the liquid and gaseous states. By H. Ziebland and J. T. A. Burton.

The thermal conductivity of nitrogen and argon was measured with a vertical coaxial cylinder apparatus. The investigation included the critical region and covered the temperature range 85 to 200°K at pressures between 1 and 135 atm. The results obtained in this research agree well with those obtained by most other authors.

Reflexion electron microscopy at high angles. By D. H. Page.

A commercial electron microscope has been adapted for use as a reflexion instrument with an angle of beam deviation of 26·5°. The resolution is, in general, severely limited by the chromatic aberration arising from excessive energy losses suffered by electrons scattered through large angles. However, when both the axial and field components of the aberration are minimized, within the limits imposed by the use of a commercial instrument, a resolution of 600 Å is attained. Although this is inferior to the resolution of the reflexion microscope at low angles of deviation, the high depth of field and the greatly reduced foreshortening give rise to a highly informative and readily interpreted image. Micrographs illustrate the method applied to specimens in the chemical, biological and metallurgical fields.

An improved spray droplet technique for quantitative electron microscopy. By H. L. Nixon and H. L. Fisher.

Improvements are described to the spray droplet method of Backus and Williams for direct particle counting by electron microscopy. Decreasing the droplet size makes it possible to use much higher magnifications without sacrificing the ability to photograph each droplet trace entire on one frame, and droplets of the desired size are sorted and collected in a reproducible manner in a cascade impactor. The technique is also useful for studying the state of aggregation of a suspension.

Some factors affecting the accuracy of measurement of the polystyrene latex standard particles are discussed. Different methods yield different values, and there is at present no valid basis for selecting the best estimate.

A property of a buckled elastic rod. By G. A. V. Leaf.

One shape assumed by a perfectly elastic rod buckled by appropriate forces and couples at its ends is studied. It is shown that the ratio of maximum height to maximum width is independent of the material of the rod. Also, this ratio is linearly related to the distance between the ends of the rod expressed as a fraction of its length, provided the fraction is roughly less than one half.

The influence on the stress distribution in an adhesive lap joint of bending of the adhering sheets. By A. S. McLaren, A.Inst.P., and I. MacInnes, Grad.Inst.P.

The mathematical analysis of Goland and Reissner of the effect of deformation due to load is examined photoelastically and extended to cover the wider range of such like deformations. It is shown that introduction of a bending moment in the sheets opposite to that occurring in the conventional joint can produce a stress distribution on the glue line free from high normal stresses and fairly uniform in shear. A modified design of lap joint to ensure this is proposed.

SCIENTIFIC OFFICERS required by Ministry of Supply at research and development establishments mainly in South of England, for work in physics, electronics, electrical mechanical or aeronautical engineering, applied mathematics, metallurgy or chemistry. Qualifications : first—or second—class honours degree in appropriate subject, or equivalent. Candidates should indicate fields of work in which interested. Starting salary in range £595–£1,080 p.a. (superannuable) according to research experience. Rates for women somewhat lower but reaching equality in 1961. Forms from M.I. & N.S., Technical and Scientific Register (K), 26 King Street, London, S.W.1, quoting A 8/8A.

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Automatic Telephone & Electric Co. Ltd., Liverpool, have a vacancy for a qualified Physicist in their Laboratories at their main Works in Liverpool.

Candidates should possess Graduate or equivalent qualifications with some knowledge of Chemistry.

The successful candidate will be expected to carry out investigations on insulating materials, dielectric materials, plastics and other similar topics of applied industrial Physics. The work is interesting and it is hoped that the candidate appointed will ultimately be able to qualify for a position of responsibility in the Department. Some experience in the above field of work is desirable but not essential.

The post will be on permanent staff with generous contributory pension fund.

Full particulars of age, qualifications and experience may be sent to Personnel Manager, AUTOMATIC TELEPHONE & ELECTRIC CO. LTD., Strowger Works, Liverpool, 7.

PHYSICIST, graduate, preferably of honours degree standard required by the Research Laboratories of British Insulated Callenders Cables Ltd., Shepherds Bush, London, W.12. The work involves research and development on dielectrics and capacitors. Experience in vacuum-metallizing or ceramics would be an advantage. Five day week. Pension Fund. Applications giving details of age, qualifications and experience should be made to the Personnel Officer, 38 Wood Lane, London, W.12.

QUALIFIED PHYSICIST required for a post which involves a study of the deposition of pure materials produced by thermal and other decomposition techniques. Experience in high vacuum work and also in R.F. heating units would be an advantage. The post is of a senior nature. Please apply to the Deputy Research Manager, The Plessey Co. Ltd., Caswell Research Laboratories, Towcester, Northants.

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Applications are invited for the post of Assistant Experimental Officer to work with Liaison Officer on problems connected with the packaging of cheese. The appointment will be for two or three years in the first instance. Commencing salary within range £455 (age 20) to £645, men or £627, women, (age 26 or over).

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The Company have a vacancy for a spectroscopist at their Research and Development Department, Epsom, Surrey. Candidates, who should be aged not over 30, must hold a good honours degree in an appropriate branch of science, preferably Chemistry. Although experience of spectroscopy, either academic or industrial, is desirable, candidates interested in this type of work, but without previous experience, will be considered.

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HONOURS GRADUATES in electrical engineering, physics or mathematics with at least five years' experience in industrial research organizations. They should be interested in semiconductor applications, nuclear instrumentation, high sensitivity d.c. amplifiers or computors. A good knowledge of physics is more important than specialized knowledge in the above fields.

GRADUATES, electrical engineering or physics, with at least two years' experience in industry on semiconductors, magnetic amplifiers or instrumentation. Applicants having Higher National Certificate or likely to obtain it in 1958 will be considered for these posts, which will afford good opportunities for independent research.

Please write to Dept. C.P.S., Marconi House, 336/7 Strand, W.C.2, giving full details and quoting ref. PB 2970P.

WELSH COLLEGE OF ADVANCED TECHNOLOGY
CATHAYS PARK, CARDIFF

ASSOCIATESHIP SANDWICH COURSE IN APPLIED PHYSICS

A four year Sandwich Course, leading to a College Associateship, will commence in October, 1958.

The Institute of Physics has approved this course, and the Associateship will satisfy completely the Institute's academic requirements for Graduateship and corporate membership.

Students may be " works " or " college " based, and will spend alternate six monthly periods in College and Industry.

Normal requirements for admission to the course will be success at G.C.E. "A" level or O.N.C. at a high standard, in Applied Physics or Electrical Engineering.

Details of the course may be obtained from, and applications should be made to, the Principal.

R. E. Presswood,
Clerk to the Governors.

HIVAC LTD., a Company associated with a major group in the telecommunications field, requires scientific and technical staff to work on the development and production of valves, cold cathode tubes and similar products. Applications are invited from PHYSICISTS, CHEMISTS and ENGINEERS, having a degree or equivalent qualification and interested in these fields. Previous experience is not essential, except for the more senior appointments, for which the ability to work with the minimum of supervision is required. The posts are pensionable and offer considerable scope for advancement and vacancies are available at both Harrow-on-the-Hill and South Ruislip. Applications, which will be treated in strict confidence, should be addressed : The Engineer-in-Chief, Hivac Ltd., Stonefield Way, Victoria Road, South Ruislip.

KINGSTON UPON HULL EDUCATION AUTHORITY
COLLEGE OF TECHNOLOGY
Principal : Emlyn Jones, M.Sc., F.R.I.C.

Required, to commence duty as soon as possible, Assistant (Grade B) for Physics. Candidates should possess a degree and preferably have teaching experience. Industrial experience would be an added qualification. Salary : Burnham Technical Scale. £650 × £25–£1,025 with additions for training and graduate qualifications and increments for suitable teaching and/or industrial experience.
Further particulars and application forms, to be returned as soon as possible, will be supplied by the Chief Education Officer, Guildhall, Kingston-upon-Hull.

BRADFORD INSTITUTE OF TECHNOLOGY
(College of Advanced Technology)

PRINCIPAL : E. G. EDWARDS, Ph.D., B.Sc., F.R.I.C.

Applications are invited for the following posts :
Senior Lecturer in Physics
Lecturer in Physics

Candidates should be well-qualified physicists with teaching and/or research and/or industrial experience. Salaries for men, according to the Burnham Technical Award, are as follows :

Senior Lecturer : £1,350 – £1,550 per annum
Lecturer : £1,200 – £1,350 per annum

Previous industrial or research experience at a suitable level may be taken into account in fixing the commencing salary.
Further particulars and application forms may be obtained from the Registrar, Institute of Technology, Bradford, 7.

W. H. Leathem,
Clerk to the Governors.

IMPERIAL COLLEGE OF SCIENCE AND TECHNOLOGY

Applications invited from honours graduates in chemistry or physics for immediately-available bursaries of about £400 p.a. to carry out fundamental research on combustion and flame propagation, normally leading to Ph.D.
Applications with curriculum vitae to Dr. J. H. Burgoyne, Department of Chemical Engineering, Imperial College, S.W.7.

THE ENGLISH ELECTRIC CO., LTD.

require

a PHYSICIST

in the Valve Materials Laboratory of the Nelson Research Laboratories, Stafford, to apply his fundamental knowledge and experience to

MATERIAL DEVELOPMENT AND APPLICATION

in valve and semi-conductor device construction.

The salary will be between £800 – £1,200 per annum, a superannuation scheme is in operation and housing problems will be discussed. Please write giving full details to Dept. C.P.S., 336/7 Strand, W.C.2, quoting Ref. PB913H.

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APPOINTMENT OF ELECTRONICS OFFICER

The British Ceramic Research Association has a vacancy in the Scientific Officer or Senior Scientific Officer grades for a graduate with special knowledge and experience of electronics. The work includes a number of problems of instrumentation and control within the industry, the development of laboratory techniques and the possible study of the application of microwaves to ceramic research.

Applications, stating age, qualifications and experience, should be sent to The Director of Research, The British Ceramic Research Association, Queens Road, Penkhull, Stoke-on-Trent.

The Institute of Physics

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H. L. PENMAN, PH.D., F.INST.P., *Head of Physics Department, Rothamsted Experimental Station*

After summarizing the fundamentals of the subject many methods of measuring and controlling humidity are described. A good grasp of some parts of this monograph and a general understanding of all of it should be a prerequisite for those concerned with the problems of atmospheric and soil humidity.

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J. TOPPING, PH.D., F.INST.P., *Principal, Acton Technical College*

Every teacher of experimental physics knows how " results " given to three or four decimal places are often in error in the first place ; students suffer from " delusions of accuracy." At a higher level too, more experienced workers sometimes claim a degree of accuracy which cannot be justified. A consideration of the topics discussed in this monograph may stimulate in students an attitude to experimental results at once more modest and more profound.

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The Institute of Physics, 47 Belgrave Square, London, S.W.1

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This volume contains the texts of the 158 papers presented to the 3rd International EM meeting. It comprises 724 pages with 189 plates and numerous line illustrations. The communications (with discussion) are arranged under the following headings :

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The volume is bound in cloth-covered boards, and is presented in the style and format of the Journal of the Royal Microscopical Society. The price is £4 10s. 0d., post paid, from the office of the Society, but £2 10s. 0d., post paid (one copy only), to registered participants in the 1954 Conference who have already placed their order. Orders should be placed with the Assistant Secretary, Royal Microscopical Society, Tavistock House South, Tavistock Square, London, W.C.1, or any bookseller.

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Appointments Vacant

The inclusion of particulars of a vacancy must not be taken to imply that the Institute necessarily approves of the terms offered or that might be offered. Candidates should satisfy themselves that these are satisfactory, and they may always refer to the Institute for advice.

NATIONAL PHYSICAL LABORATORY. Pensionable post of Superintendent in the Modern Physics Division of the Laboratory at Teddington, Middlesex. The Division is a newly created one concerned largely with developments in modern physics (non-nuclear) having potential applications to industry. Candidates should have high scientific qualifications, including experience in research and in the direction of research in modern experimental or theoretical physics. Those without high formal qualifications but of high professional attainment may be considered. Opportunities to develop own line of research.
Salary scale £2.500–£2,800. Women's pay equal by 1961.
Write Civil Service Commission, 30 Old Burlington Street, London, W.1, for application form, quoting No. S4806/58. Closing date March 28, 1958.

THE UNIVERSITY OF SHEFFIELD

Three Postgraduate Research Bursaries are available in the Department of Fuel Technology and Chemical Engineering, two for work on the Physics and Physical Chemistry of combustion in bench type rigs and the third for research on the Physical Chemistry of soot formation in large flames to be carried out primarily at the International Flame Radiation Centre at Ijmuiden. Value in the range £350–£500 per annum plus fees. Applications should be sent to the Registrar as soon as possible.

ENGINEERING AND PHYSICS IN MEDICAL RESEARCH

The Medical Research Council invite applications from junior physicists or junior electronic engineers for a vacancy at the National Institute for Medical Research. The work involves development of specialized laboratory instruments and equipment in consultation or collaboration with staff in various scientific divisions. The work is extremely varied and would be both congenial and satisfying to the right man who should be able to express ideas quickly and simply in terms of circuits and hardware. Applicants, preferably over 26 years of age, should possess an appropriate degree, or City and Guilds Final (Telecomms.) or H.N.C. Salary will be on a scale :
Junior Technical Officer £660 × £30–£780, or
Technical Officer £830–£1,150.
The appointment will be superannuated and, after a provisional period of one year, established.
Application forms obtainable from Personnel Officer, National Institute for Medical Research, The Ridgeway, Mill Hill, N.W.7.

PHYSICISTS/CHEMISTS required with research or production experience on electrical materials or components. Senior salary between £1,000 and £1,750, Junior £700 and £1,000. G. V. Planer Ltd., Windmill Road, Sunbury, Middlesex.

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Several Graduates in Electrical Engineering or Physics or holders of the H.N.C. in Electrical Engineering, are required in a High Voltage Research Laboratory for experimental research on High Voltage Problems associated with surge diverters and other products of the Company. The work covers a wide range and includes the construction and use of impulse voltage and inpulse current generators, high direct voltage generators, and electronic equipment.

Candidates should be able to carry out investigations without close supervision.

Previous works' training and laboratory experience are desirable.

The appointments are permanent and pensionable : and starting salary will be in accordance with qualifications.

Applications, quoting reference Q.10, giving details of age, qualifications and experience should be made to :

Personnel Manager,
Metropolitan-Vickers Electrical Co. Ltd.,
Trafford Park,
Manchester, 17.

PHYSICISTS required by The Atomic Weapons Research Establishment, Aldermaston, Berkshire. To undertake work in the field of electrical physics, devising novel items and proving their feasibility for special application. 1st or 2nd class honours degree in physics required. A working knowledge of electronics and experience in one or more of the following fields an advantage : gas discharges, detonation processes, solid state physics.
Salary : To be assessed according to age, qualifications and experience within the scale £645–£1,120 p.a. Contributory Superannuation Scheme. A house or assistance towards legal expenses on house purchase will be available for married officers living beyond daily travelling distance.
Postcards for application forms to the Senior Recruitment Officer, at the above address. Please quote ref. A/1640/110.

GRADUATE PHYSICIST—or a prospective 1958 graduate—for research on the interaction of a porous material (paper) and a solid/liquid system (ink). Experience of fluid flow is advantageous but the principal qualification is a genuine interest in fundamental science. Salary on scale £650–£1,100 according to qualifications and experience. F.S.S.U. Five day week. Application forms from the Secretary, Printing, Packaging and Allied Trades Research Association, Randalls Road, Leatherhead, Surrey. Ref. Pr/pr.

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(xiv) To conduct experiments for verification of new ideas, particularly relating to control systems. Ref. No. 141/ER/IP

Candidates for senior posts are expected to have a University Degree and/or H.N.C. For the junior posts, O.N.C. acceptable. Proven experience in one or more fields indicated would be an alternative to academic qualifications. Salary commensurate with qualifications and experience. Staff Pension Scheme. Write for application form, quoting appropriate reference, to Personnel Manager, Smiths Aircraft Instruments Ltd., Bishops Cleeve, Nr. Cheltenham, Glos.

EDITORIAL VACANCIES, monthly publication *Science Abstracts* (Section A—Physics): Section Editor, commencing salary £1,200–£1,400. Assistant Editor, £850–£950, both according to age and experience. Physics degree and knowledge of physics literature essential. Progressive posts. Pension scheme. Five-day week. Apply Secretary, The Institution of Electrical Engineers, Savoy Place, W.C.2.

MIDDLESEX COUNTY COUNCIL—EDUCATION COMMITTEE

Two Laboratory Assistants required in Physics Department at Brunel College of Technology, Woodlands Avenue, Acton, W.3. For first post, applicants should be of G.C.E. Advanced Level standard with experience in teaching laboratory or industry. For second post, preference given to woman with at least three passes at Ordinary level in G.C.E., experience in stock records and ability to type. Salary Misc. III £470–£550 p.a. plus London Weighting. Prescribed conditions. Apply stating age, experience and qualifications to Principal (Quote X.7 B.I.P.), Canvassing disqualifies.

THE ROYAL COLLEGE of SCIENCE AND TECHNOLOGY

(Affiliated to the University of Glasgow)

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LECTURESHIP IN PHYSICS

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A Microwave Valve Development Group requires a THEORETICAL PHYSICIST with some postgraduate experience in the Electron Optics or Microwave fields. A good honours Degree in Mathematics or Physics is desirable. Salary commensurate with qualifications and experience. Please apply to the Personnel Manager (Ref. 679), Elliott Brothers (London) Ltd., Borehamwood, Herts.